Neutron capture study by ANNRI

The 3rd workshop on Level Density and Gamma Strength
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Univ. of Oslo

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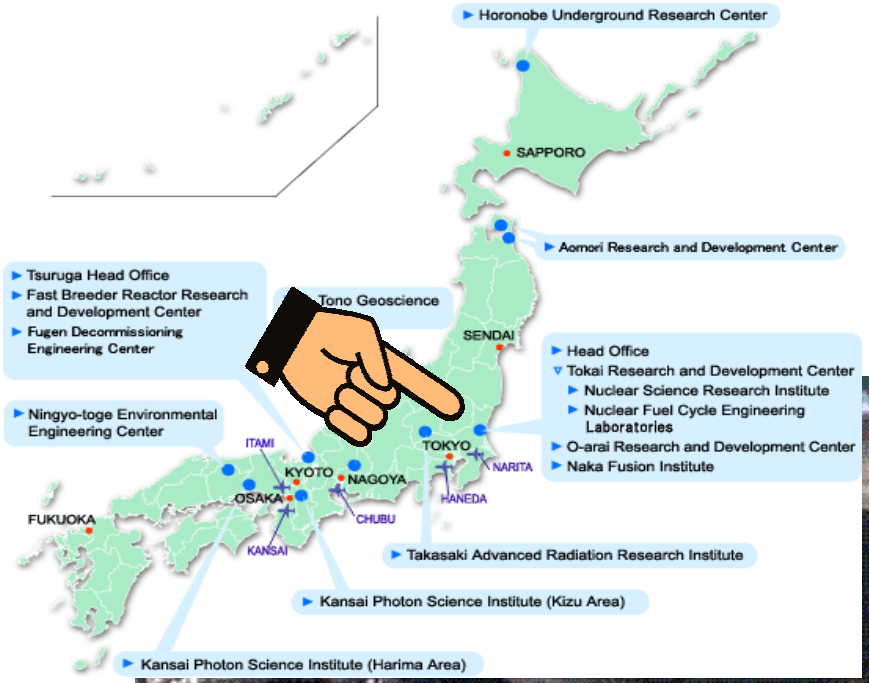
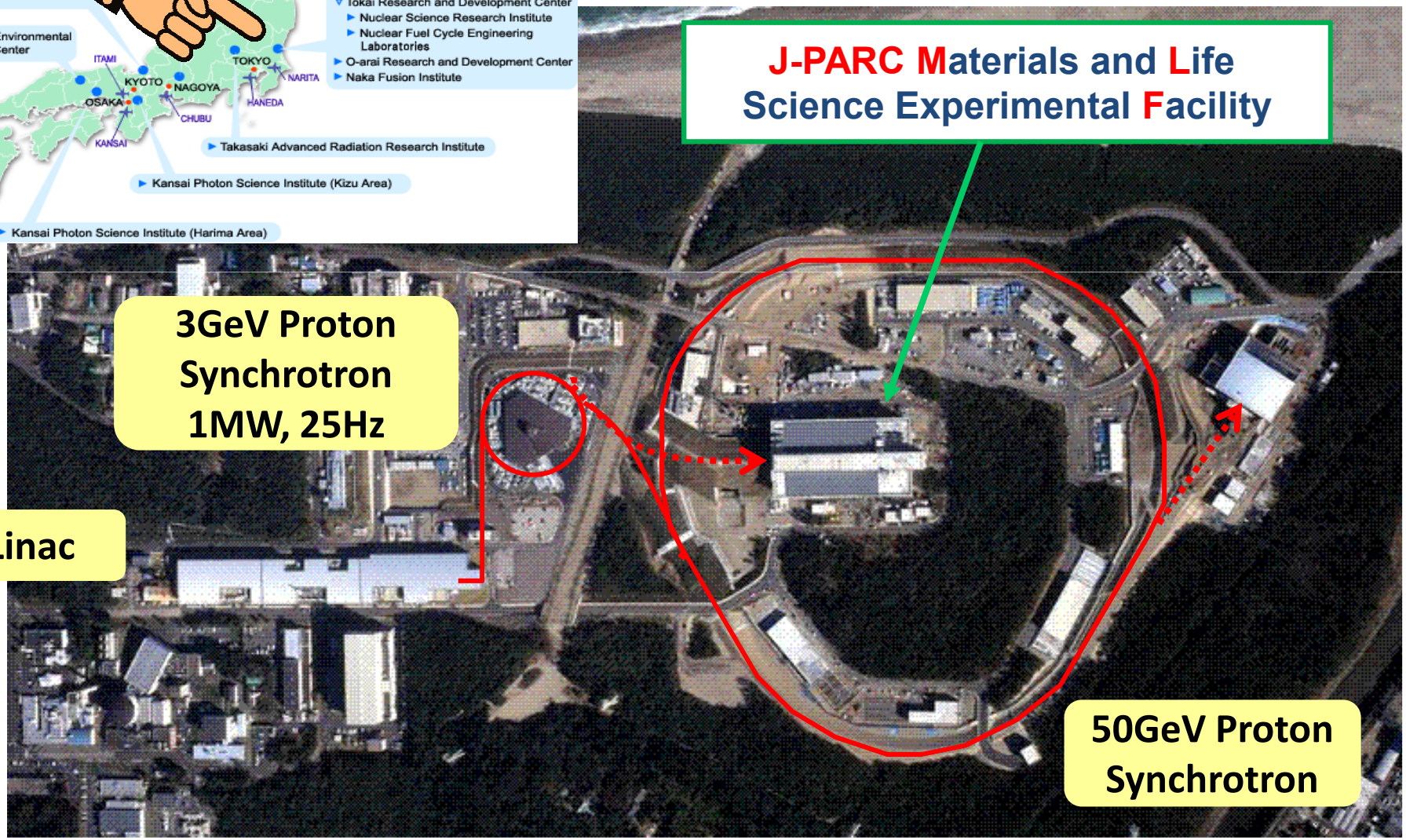
Locations of Facilities

Japan Proton Accelerator Research Complex : J-PARC

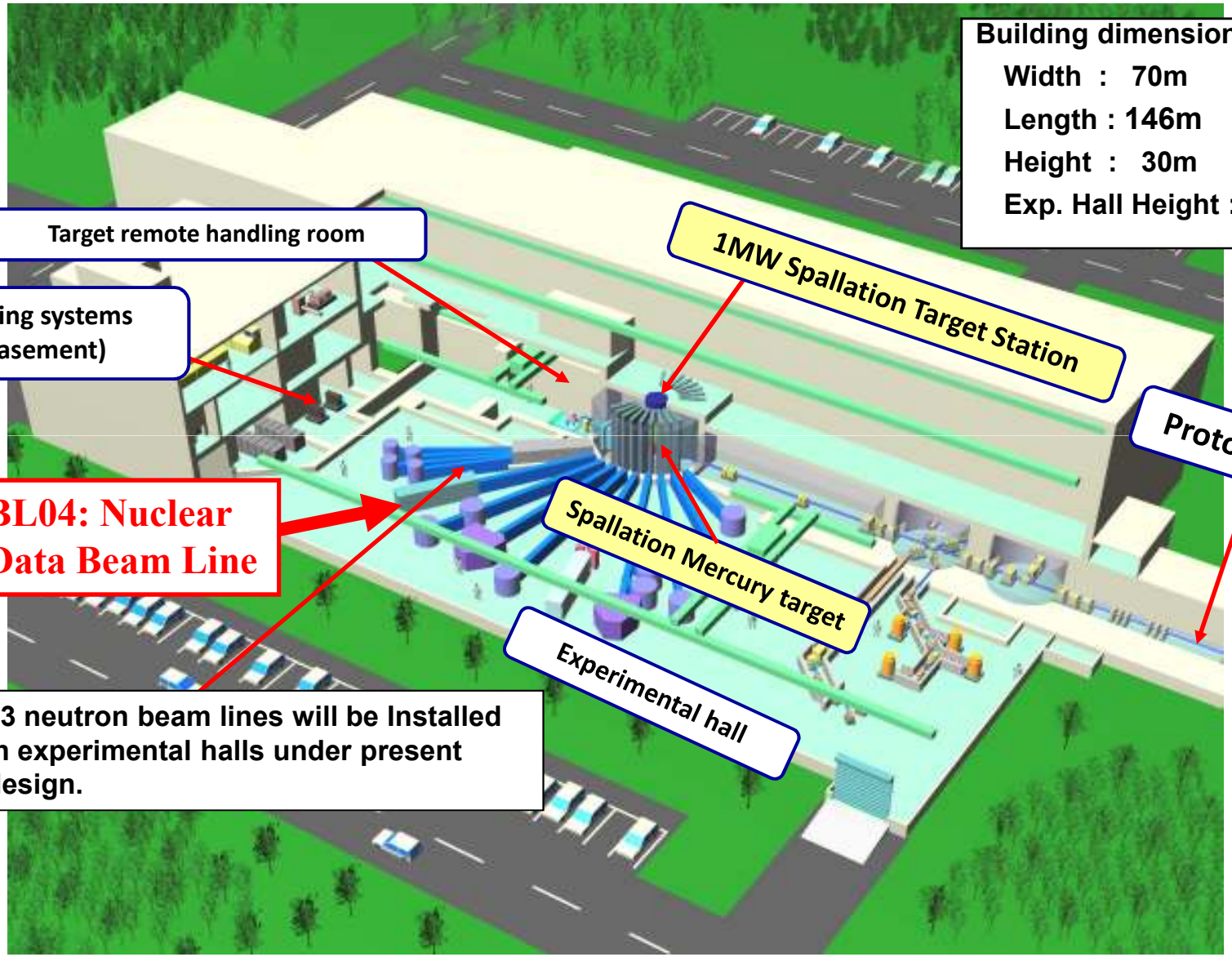




Materials and Life Science Experimental Facility

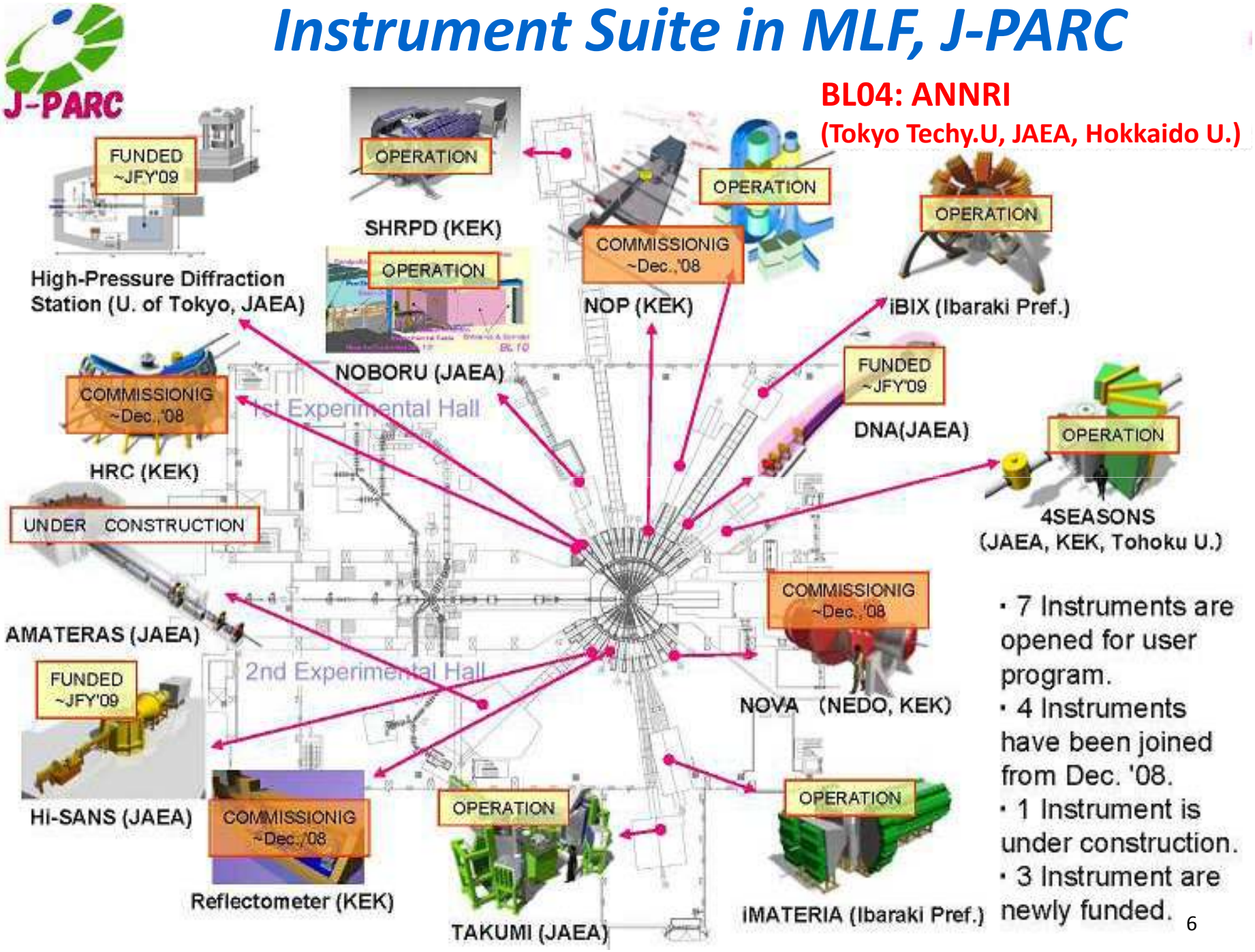
J-PARC MLF, Taken from HP of J-PARC

Materials and Life Science Experimental Facility



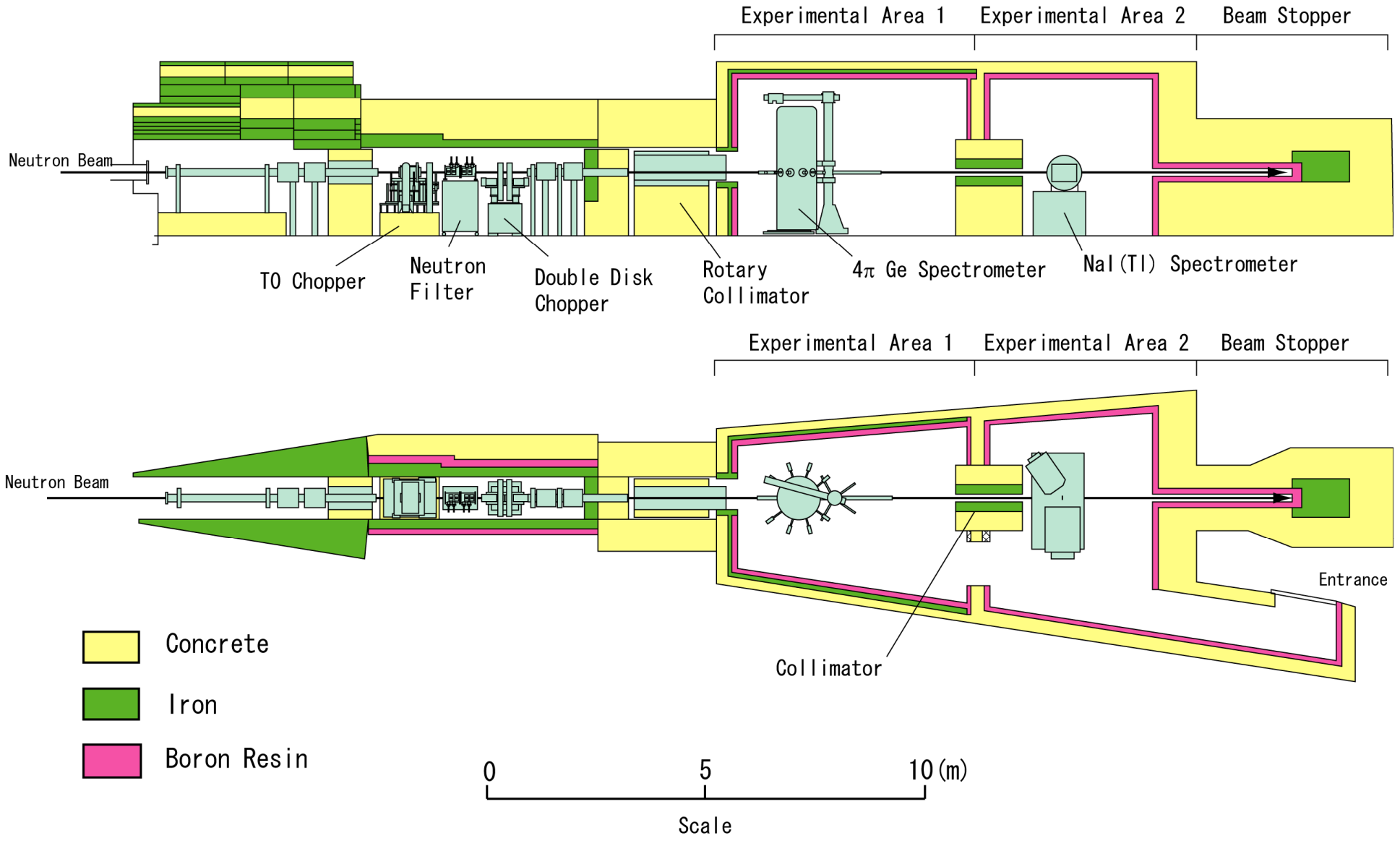
J-PARC MLF, Taken from HP of J-PARC

Instrument Suite in MLF, J-PARC

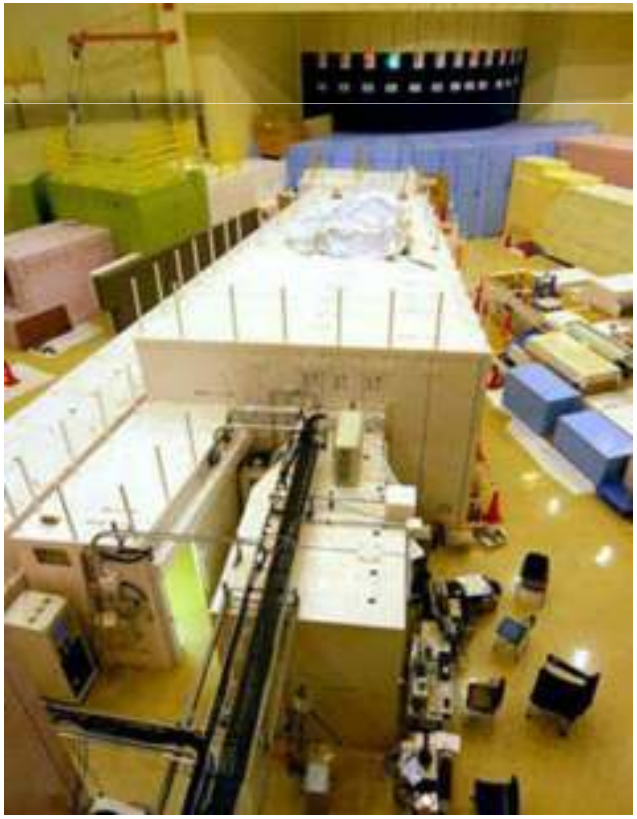


- 7 Instruments are opened for user program.
- 4 Instruments have been joined from Dec. '08.
- 1 Instrument is under construction.
- 3 Instrument are newly funded.

Accurate Neutron –Nucleus Reaction Instrument: ANNRI

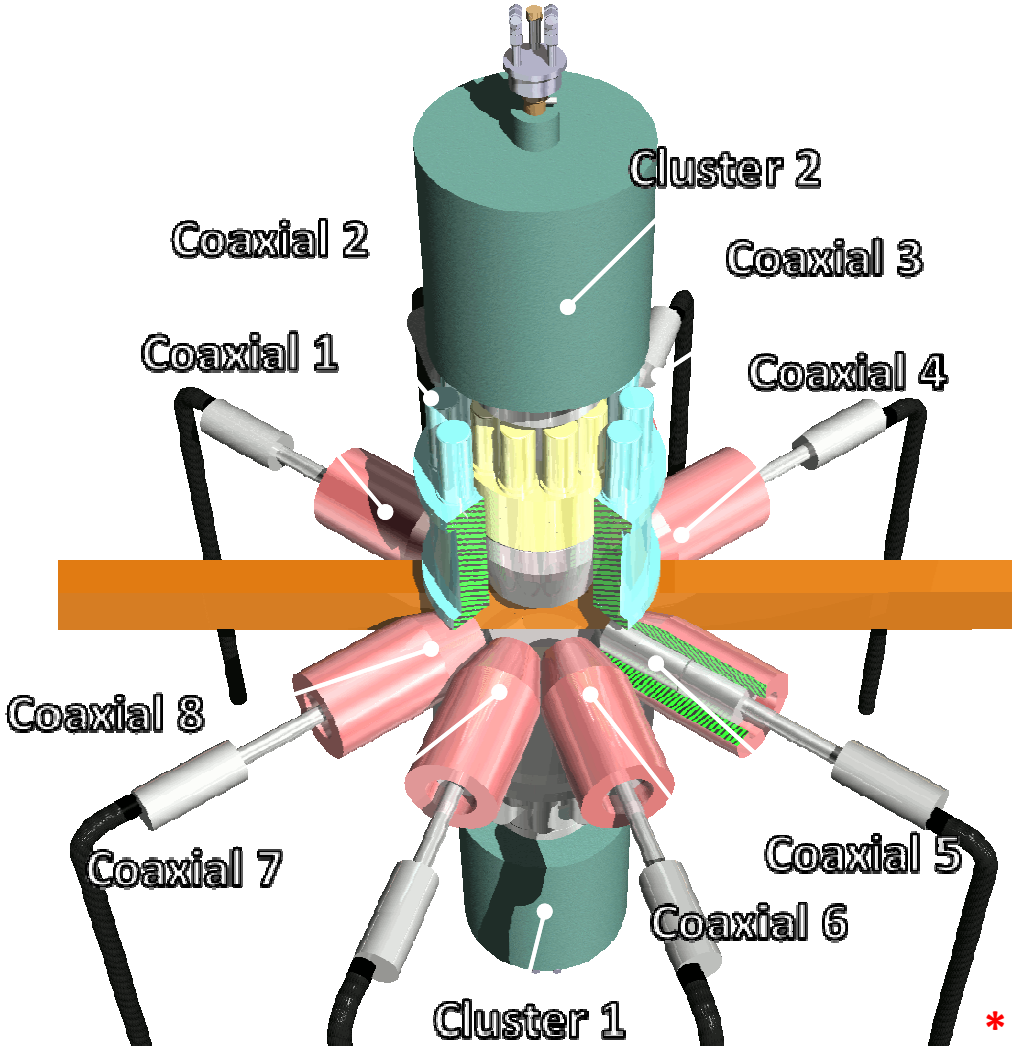


Accurate Neutron –Nucleus Reaction Instrument: ANNRI



Neutron Source: J-PARC/MLF
3GeV Proton Spallation
Beam Condition: 120 kW, 25 Hz
Pulse Width : 100 ns（double bunch）
Beam Line : BL04
Flight Path : 21.5m, 27m
Notch filters : Mn, Co, In, Ag, Cd

Measurement of Neutron-Capture Cross Section with 4πGe detector at ANNRI

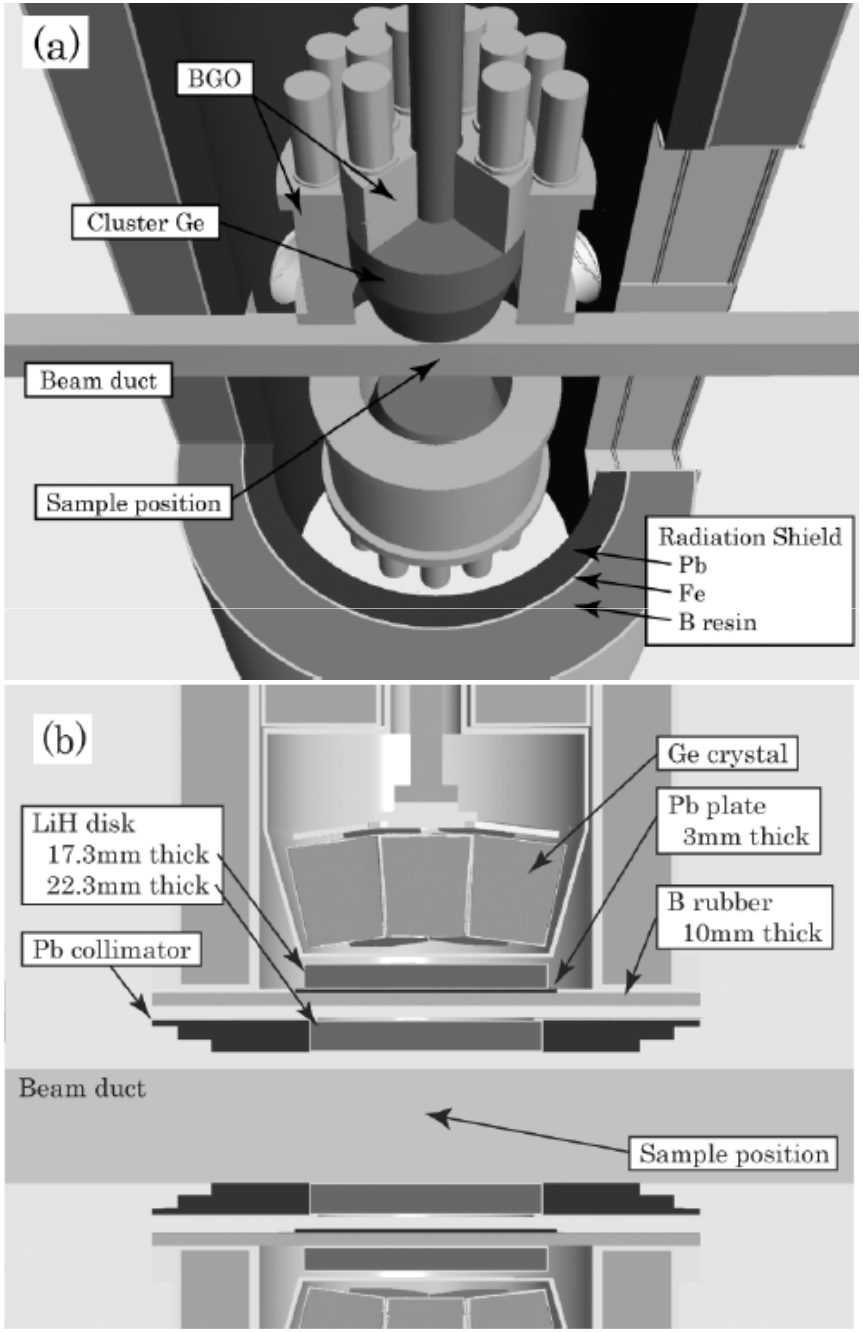


Two Cluster-type Ge detectors:
2 x 7ch＝14ch
Eight Coaxial-type Ge detectors：
8 x 1ch＝ 8ch
Total: 22ch

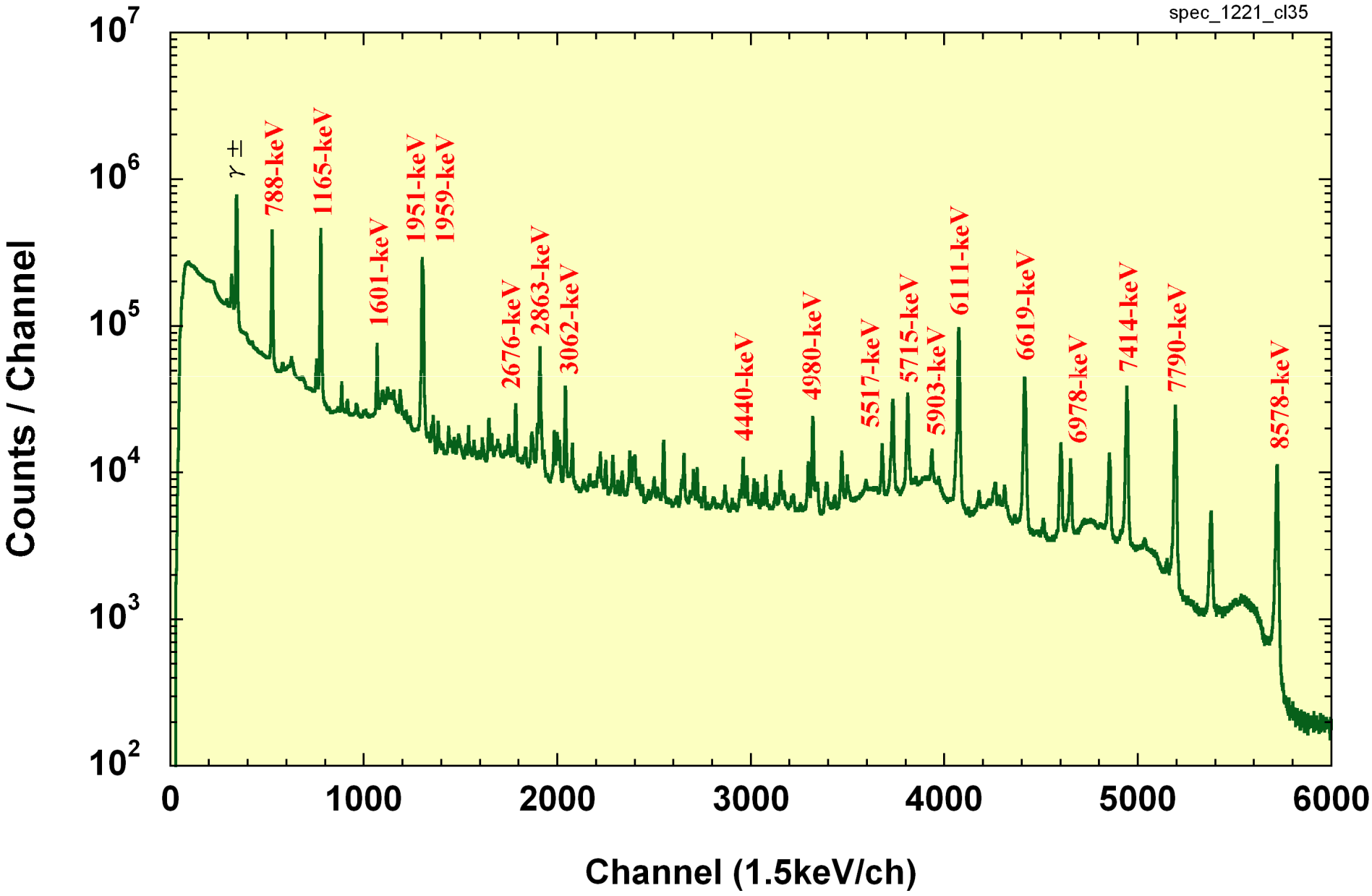
Energy Resolution * @1.33MeV:
9.8 keV (On beam)
2.4 keV (Off beam)
Peak Efficiency @1.33MeV:
3.64 ± 0.11 %
Time Resolution (DAQ):
10 ns (Max 16.7ms)
Max.Event Rate (DAQ):
300 k events/s.

* T. Kin *et. al., the 2009 NSS-MIC Conf. Rec.* , N24-2, (2009).

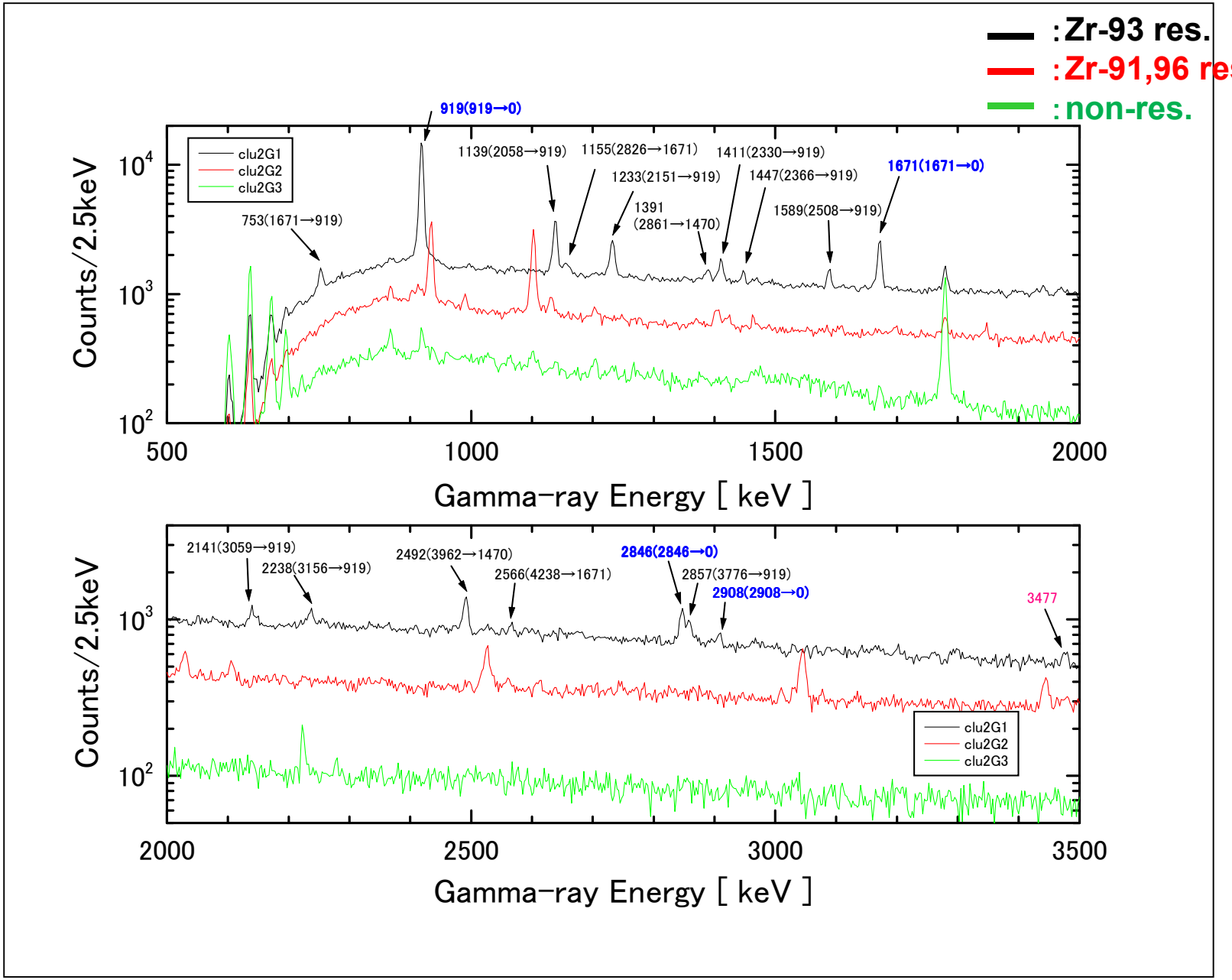
Two Cluster Ge detectors with BGO anti-coincidence shields

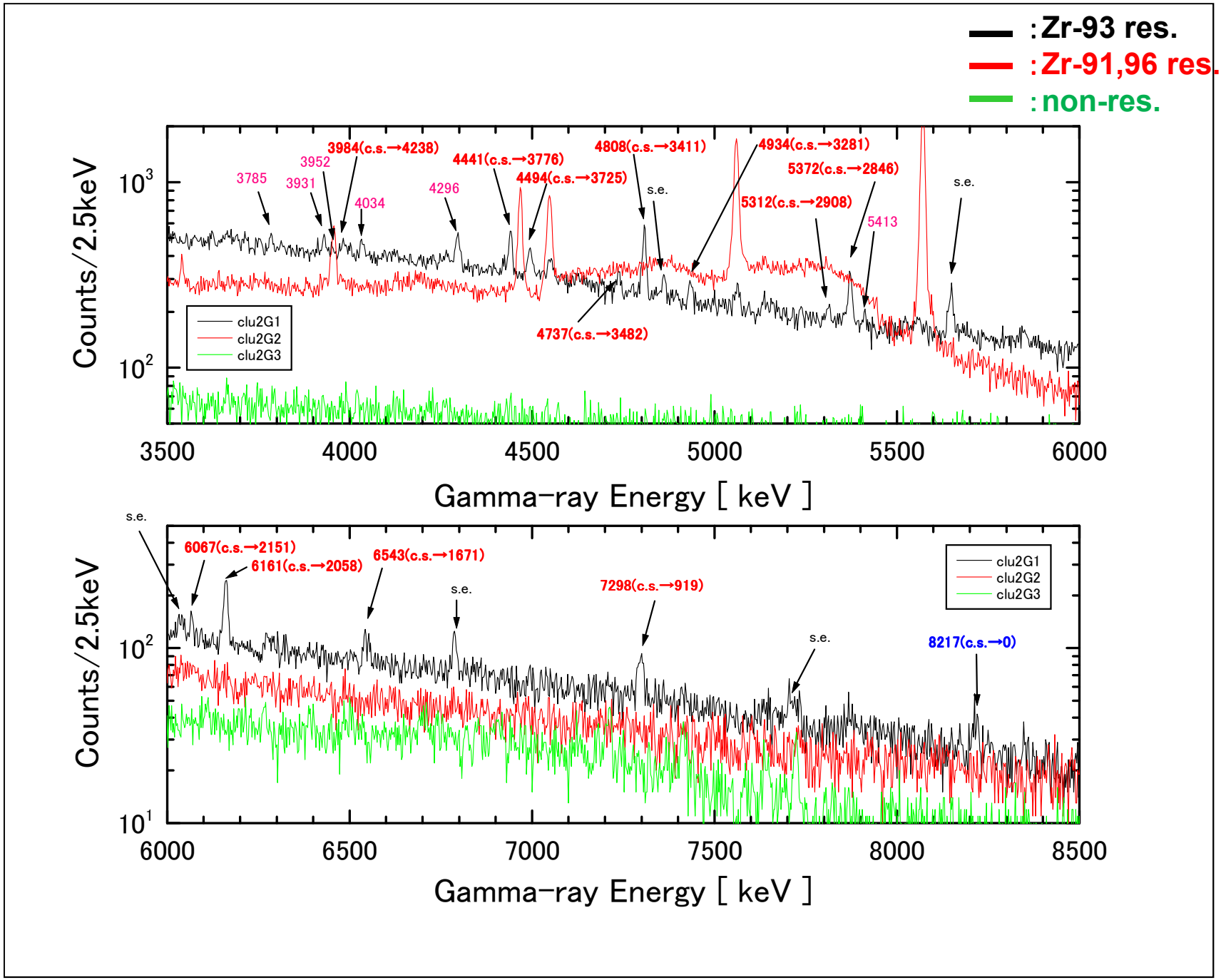


Capture γ-ray spectrum of Cl-35



P.H. Spectra gated by TOF regions

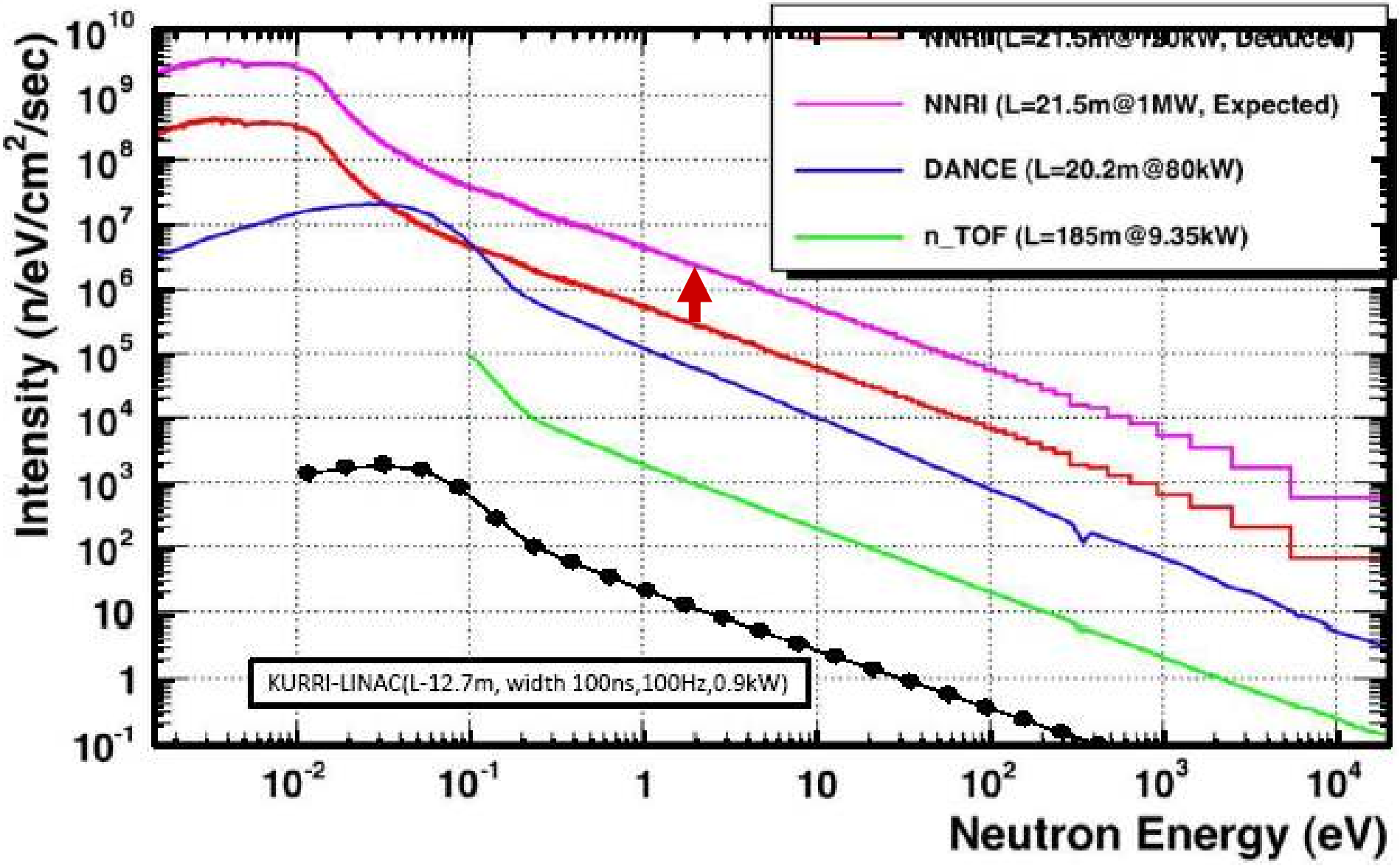



: Zr-93 res.
: Zr-91,96 res.
: non-res.
Counts/2.5keV
Gamma-ray Energy [keV]
clu2G1
clu2G2
clu2G3
3785
3931
3952
3984(c.s.→4238)
4034
4296
4441(c.s.→3776)
4494(c.s.→3725)
4737(c.s.→3482)
4808(c.s.→3411)
s.e.
4934(c.s.→3281)
5312(c.s.→2908)
5372(c.s.→2846)
5413
s.e.
s.e.
6067(c.s.→2151)
6161(c.s.→2058)
6543(c.s.→1671)
s.e.
7298(c.s.→919)
s.e.
8217(c.s.→0)

Pulsed neutron sources

Facility Reference	Beam energy	Beam power n Intensity	Beam pulse width Pulse per sec	Flux
IRMM, GELINA ND2007, p.563	Electron 100 MeV	6 kW	1 ns 800 Hz	@ 12 m
ORNL, ORELA ND2007, p.441	Electron 180 MeV	5 kW 10^{13} n/s	8 ns 525 Hz	@ 40 m
Kyoto, e Linac ND2007, p.591	Electron 30 MeV	1 kW	100 ns 100 Hz	@ 10 m
CERN, n-TOF ND2007, p.537	Proton 20 GeV	9 kW 10^{15} n/s	6 ns 0.4 Hz	4×10^5 n/cm^2/s @ 185 m
LANL, Lujan ND2007, p.415	Proton 0.8 GeV	80 kW	135 ns 20 Hz	@ 20 m
J-PARC, MLF (Expected)	Proton 3 GeV	1 MW $\sim 10^{17}$ n/s	$\sim$100 ns 25 Hz	$\sim 10^9$ n/cm^2/s @ 22 m

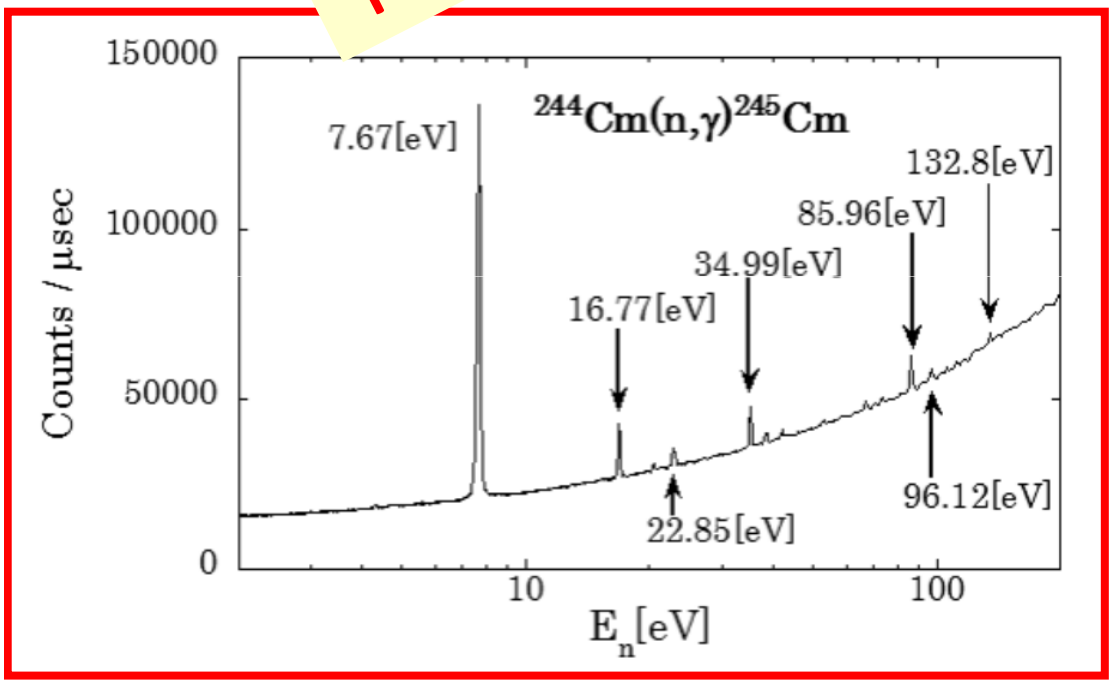
Comparison of neutron fluxes at other facilities



Some of Highlight Data

Measurement of ^{244}Cm at J-PARC/MLF/ANNRI

Preliminary

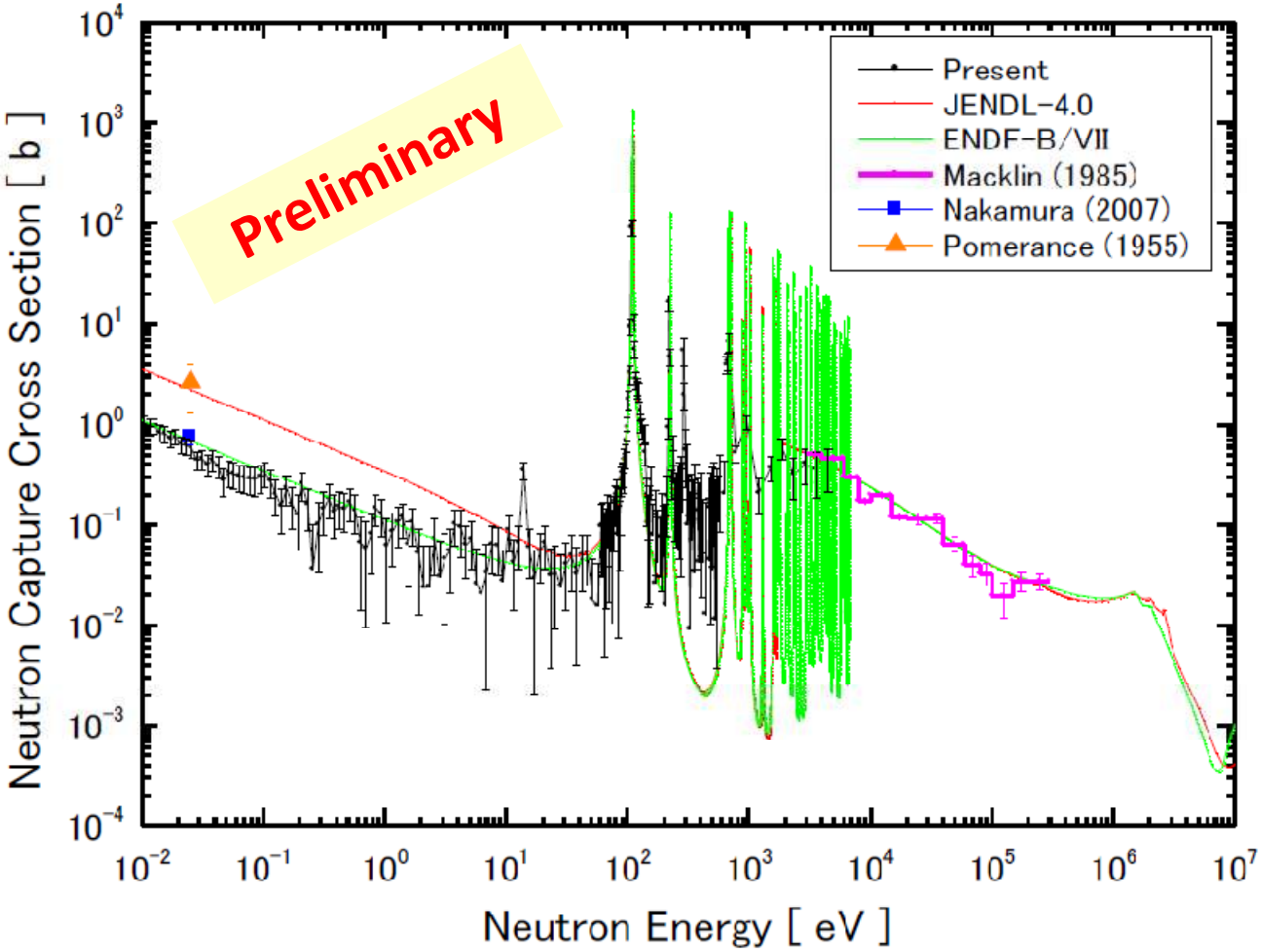


E_n[eV]	Present work	JENDL-3.3
7.67	1.0	1.0
16.77	0.1191 ± 0.0020	0.0981
22.85	0.0352 ± 0.0017	0.0315
34.99	0.1142 ± 0.0034	0.1022
85.96	0.1047 ± 0.0052	0.1643
96.12	0.0960 ± 0.0089	0.0593
132.8	0.0747 ± 0.0084	0.0779

∗ The total systematic uncertainty : 6 %.

S.Goko *et al.*, J.Nucl.Sci.Technol, 47, p.1097 (2010).

Neutron Capture Cross Sections of Zr-93



Thermal-neutron capture cross section

Present（Preliminary）:(Lower limit:0.58±0.07),estimated 0.70±0.08b

Nakamura et al.(2007) :(Lower limit:0.63±0.02),estimated 0.76±0.13b

JENDL-4 :2.239 b, ENDF-B/VII : 0.695 b

Summary

The operation of a new experimental apparatus called “ANNRI” in the MLF @at J-PARC has been started for neutron-capture cross section measurements of MAs and FPs.

Advantages of *ANNRI*: Intense Neutron Flux and High Resolution

Open for users on following research fields:

- Nuclear Data Measurements for advanced reactor systems
- Nuclear Astrophysics
- Radionuclide Quantification
- Multiple prompt gamma-ray analysis

…… etc.

Damage after Great East-Japan Earthquake on 11 March, 2011

near Linac Facility

Damage after Great East-Japan Earthquake on 11 March, 2011

3GeV Synchrotron

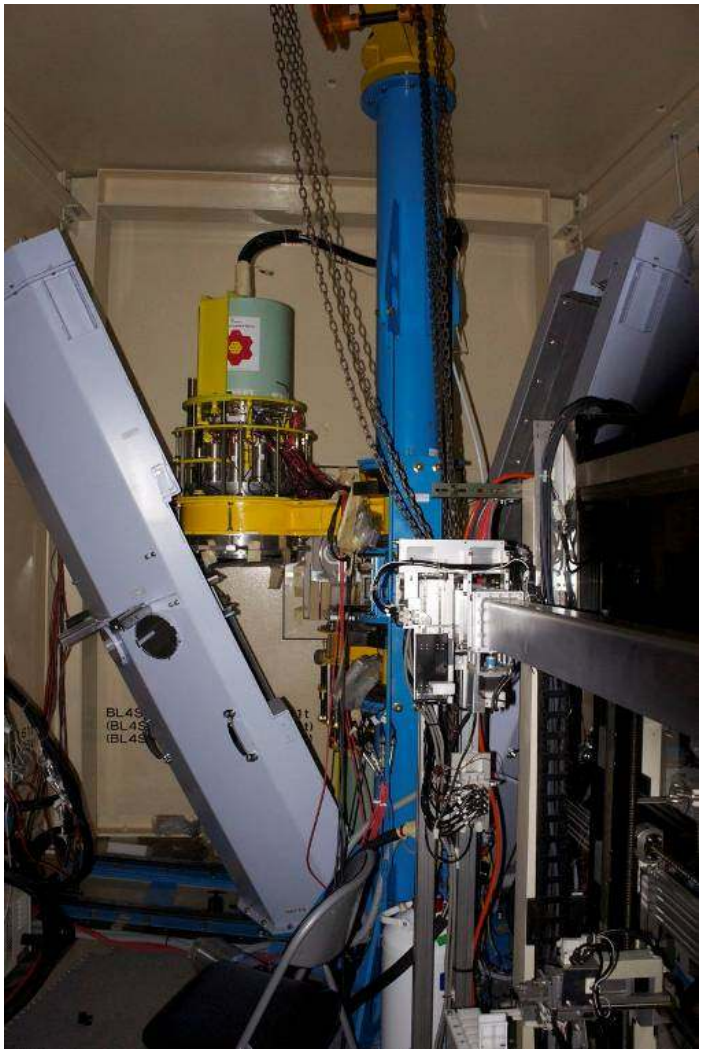
Damage after Great East-Japan Earthquake on 11 March, 2011

Main Control Room

50GeV (MR) Synchrotron

Aim for Restoration

Damage after Great East-Japan Earthquake on 11 March, 2011



4π Ge detector @ANNRI

Removal of Pb shield walls

Recovery Prospects

Dec., 2011～ Beam tuning & Delivery
Jan., 2012～ 2 cycle operation
Beam power: 100-kW

Contact

If there are anything (e.g. experimental proposals), please drop a line to contact parsons:

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TEL: (+81) 029-282-6789

Sub-contact parson: Dr. Atsushi KIMURA
E-mail: kimura.atsushi04@jaea.go.jp

Thank you for your kind attention

Materials in reserve

Current status of nuclear data

Relation between Experiment and Evaluation

Thermal neutron capture cross section

	References	^{107}Pd(n, γ)
Exp	J, NST, 44, 103 (2007)	9.16 ± 0.27 b
Eva 1	Mughabghab(1981) Mughabghab(2006)	1.8 ± 0.2 b 2.54 ± 0.20 b
Eva 2	JENDL-3.3 (2002)	2.007 b

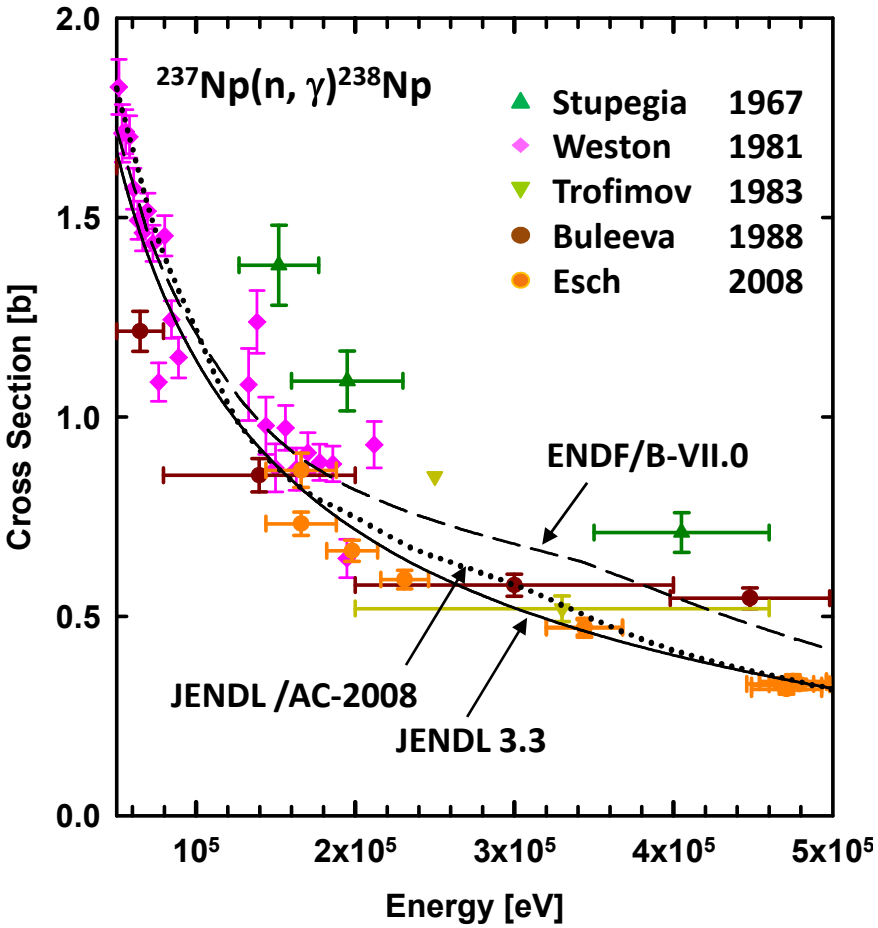
Current status of nuclear data

Examples of Uncertainties in Evaluation

References	^{244}Cm(n, f) 0.5-1.35 MeV	^{237}Np(n, γ) 0.5-1.35 MeV
J. NSE, 146, 13 2004 ANL	40 %	15 %
JENDL-3.3 2002 JAEA	7.7 %	3.4 %

Current status of nuclear data

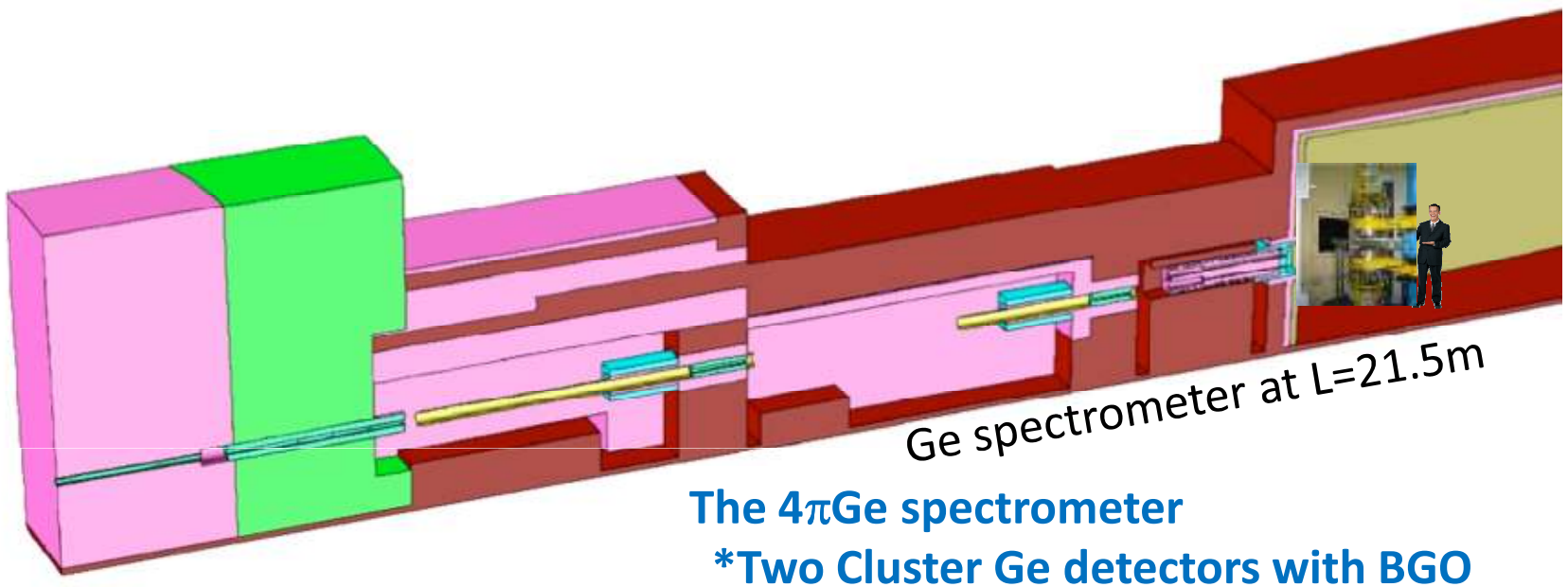
Examples of Experimental Uncertainties



How can we know the correct nuclear data ?

How can we deduce the appropriate uncertainties?

Measurement of Neutron-Capture Cross Section with 4πGe detector at ANNRI

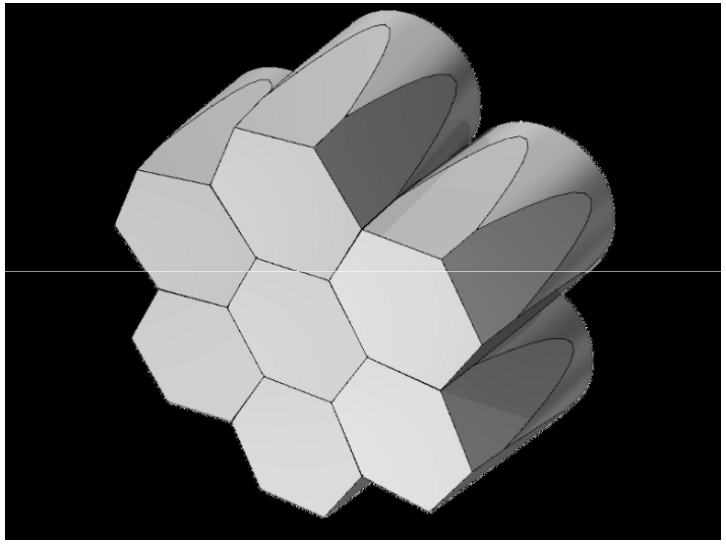


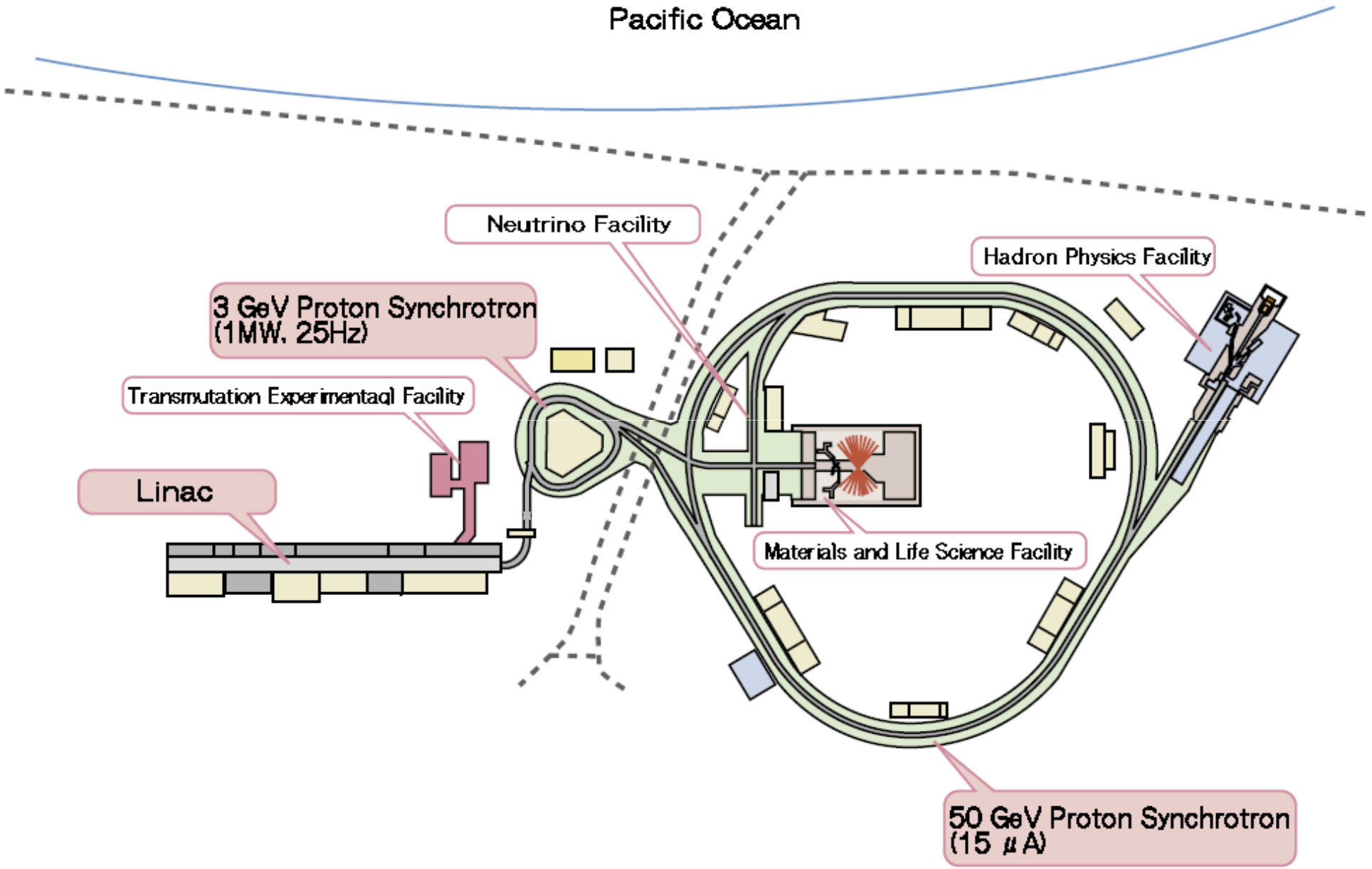
The 4πGe spectrometer

- *Two Cluster Ge detectors with BGO anti-coincidence shields were used.
- *One to Eight coaxial Ge detectors can be installed.

The beam condition

- * 120 kW, 25 Hz, Double-Bunch
- * Notch filters: Mn, Co, In, Ag, Cd




Pacific Ocean
Neutrino Facility
Hadron Physics Facility
3 GeV Proton Synchrotron
(1MW. 25Hz)
Transmutation Experimentaql Facility
Linac
Materials and Life Science Facility
50 GeV Proton Synchrotron
(15 μA)